ACCOMPLISHMENT REPORT

PROPULSION DIRECTORATE
December 1999

PROPULSION VIDEO CAPTURES MAJOR AWARD: The video "Propulsion," an overview of AFRL's Propulsion Directorate, has been chosen to receive the Omni Intermedia Award. This is a prestigious award "…created to recognize the accomplishments of outstanding media production in a variety of fields." The award has been presented to many different companies, including Dreamworks SKG, Discovery Channel, Animal Planet, Learning Channel, Arthur Andersen, Eastman Kodak, Ford, MTV, VH1, and many others. The Omni Awards are judged individually based on visual elements, audio quality, and concept development. Professionals from many highly respected companies in the industry judge the Omni Awards. Some of the judges include directors and producers from CNN, NBC News, TCI Inc, Triune Media Group, and many others. The video was produced by GRT Productions for the Propulsion Directorate, and the Line Director was John Remen. (J. Remen, AFRL/XPS, (310) 363-2567)
[More information on the Omni Awards is available at http://www.omniawards.com.]

Jacket of the "Propulsion" video

GE APPROVES JP-8+100 FOR ALL MILITARY AND COMMERCIAL ENGINES: General Electric (GE), based on their successes in the "JP-8+100 Engine Demonstration Program" with the Propulsion Directorate, recently made a major announcement. As a result of testing accomplished under this program, GE has approved the use of JP+100 in all of their military, commercial, and CFM International (CFMI) engines. CFMI is a 50/50 joint company between Snecma in France and GE in the United States. A GE representative made this announcement in December 1999 before an international audience at the American Society for Testing and Materials (ASTM) D02 Meeting on Petroleum Products and Lubricants. The +100 additive was developed by the Fuels Branch (AFRL/PRSF) in an effort to minimize maintenance costs associated with fuel degradation within aircraft fuel systems. During GE's demonstration program, numerous materials, components, and engines were successfully tested using the +100 additive. The next step for GE is to add the +100 additive to the GE fuel specification. (P. Liberio, AFRL/PRSF, (937) 255-6918)

DEMONSTRATOR ENGINE COMPLETES DETAILED DESIGN REVIEW: The Detailed Design Review of the Pratt & Whitney (P&W) XTE 67/1 Joint Technology Demonstrator Engine (JTDE) was

completed on 4 November 1999. This JTDE is P&W's initial Phase III demonstrator under the national DoD/NASA/Industry Integrated High Performance Turbine Engine Technology (IHPTET) Program. In addition to making significant progress toward the IHPTET Phase III goals, the XTE 67/1 incorporates technologies focused on transition to the Joint Strike Fighter (JSF) engine. Key component technology improvements include a lower cost moderate aspect ratio fan rotor, mistuned fan rotors to combat high cycle fatigue (HCF), fixed inlet guide vanes to lower cost, a vane passage casing treatment to improve the fan stall margin and efficiency, a counter-rotating vaneless turbine to improve thrust/weight, and a remote configuration augmentor to address low observable requirements. The combination of these technologies will produce a JTDE capable of a 69 percent increase in thrust to weight and will achieve a 35 percent reduction in production and maintenance costs. The XTE 67/1 is scheduled to begin testing in 2001. (Capt. A. Cerminaro, AFRL/PRTP, (937) 255-2767)

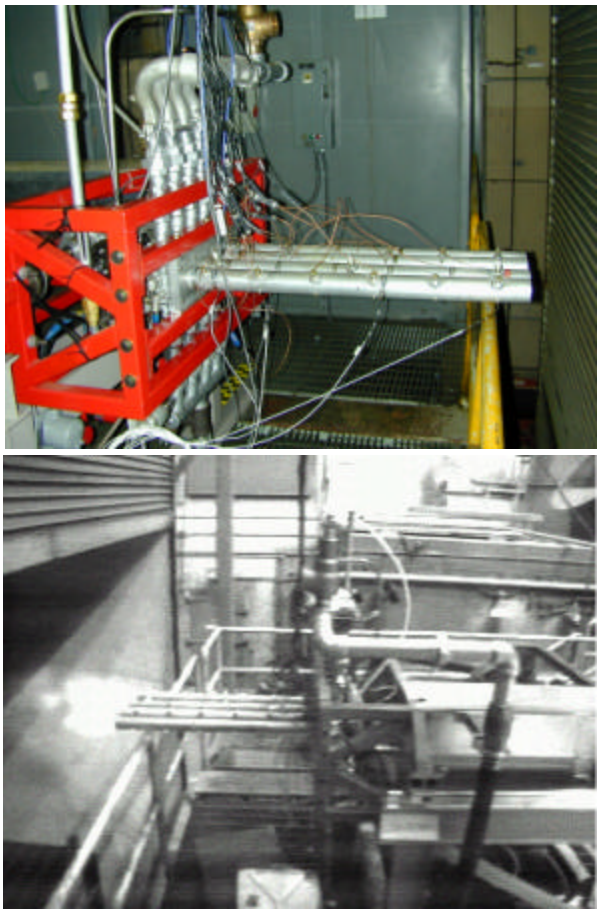
DUAL-USE PROGRAM BENEFITS POWER CONVERTER INDUSTRY: On 19 November 1999, the Propulsion Directorate's Electrical Technology Branch (AFRL/PRPE) entered into a Technology Investment Agreement with the Raytheon Company to develop power management, distribution, conditioning, and thermal management technologies for the Space Based Radar (SBR). This 40-month program has been funded with the support of the Dual Use Science and Technology (DUS&T) Program in which Raytheon has agreed to contribute over half of the funds required by the effort. The program is to demonstrate a 100-watt power converter with 90 percent efficiency in a subpanel that simulates a portion of a radar antenna. Transmit/receive modules furnished by an on-going DARPA Program will also be included in the program. The demonstrated technologies can provide improvements to military space, airborne & ground radars, processors, communications equipment, vehicles, and man-portable electronics. The industries for vehicles and portable electronics, in particular, can drive a power supply market boom over the next 3 to 4 years at a projected 11.5 percent compound annual growth rate. The power supply market is highly competitive (estimated $26 billion value) and improved power converter performance can be extremely valuable. The combined investment funding of the government and Raytheon on this DUS&T Program will accelerate the development of a highly marketable power converter by concentrating efforts on those aspects that have the greatest payback over the longest time frame. (G. Fronista, AFRL/PRPE, (937) 255-9392)

Dr. Lee Bain

BAIN RECEIVES HONORARY DOCTORATE: W. Lee Bain III of the Propulsion Directorate's High Speed Systems Branch (AFRL/PRSS) received a high honor from the Russian scientists he has been working with in recent years. He was awarded a Doctor of Honors of Philosophy in Supersonic Plasma Aerodynamics by Moscow State University (MSU). This was the first honorary doctoral degree ever conferred by the Academic Council of the Radiophysics and Electronics Section of the Faculty of Physics of Lomonosov, MSU. In addition to the honorary

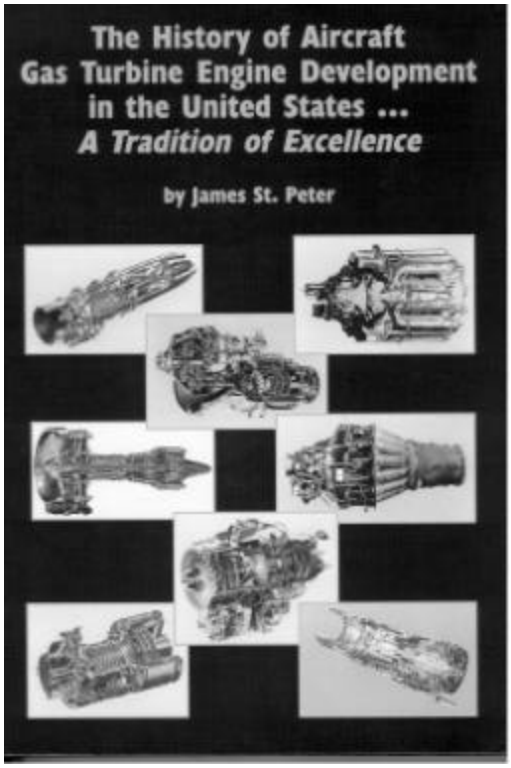
doctorate, Dr. Bain was awarded the status of Professor. Dr. Alek Androv of MSU presented the honorary degree to Dr. Bain at the 9th American Institute of Aeronautics and Astronautics (AIAA) International Space Planes and Hypersonic Systems and Technologies Conference held in November 1999 in Norfolk, Virginia. (B. Mercier, AFRL/PRSS, (937) 255-2175)

MULTI-TUBE IN-HOUSE PDE RUNS ON FIRST TRY: On 18 October 1999, the Propulsion Directorate's in-house pulsed detonation engine (PDE) was run with four detonation tubes at once. This engine, which was fired in single-tube mode for the first time in September 1999, is one of the few PDEs in the world that has successfully demonstrated multi-tube operation. Multi-tube capability is significant in that practical PDE propulsion will require the scaling, redundancy, higher aggregate frequencies, and noise abatement possible with multiple tubes firing out of phase. The research PDE, which was designed and built in-house by Combustion Branch (AFRL/PRSC) personnel, has several unique features. These features include pre-mixed operation, extremely broad frequency operating range, flexible tube configurations, and extremely low cost. The control system, which was also designed and written by PRSC personnel, performs all of the facility and engine controls and data acquisition simultaneously. The in-house PDE will be used to verify performance predictions and as a test-bed for research and development of this potentially revolutionary propulsion technology. (F. Schauer, AFRL/PRSC, (937) 255-6462)



The four-tube pulsed detonation engine (top) and the engine in operation (bottom)

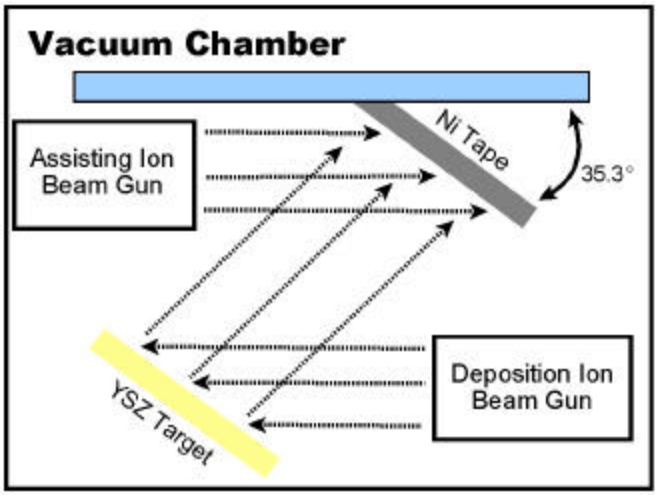
HISTORICAL PROPULSION TEXT PUBLISHED: The International Gas Turbine Institute (IGTI) recently published the definitive history of the development of the aircraft gas turbine engine in the United States. Written by James St. Peter under a contract to Universal Technology Corp (UTC), "The History of Aircraft Gas Turbine Engine Development in the United States… A Tradition of Excellence" is the first book ever published by IGTI. The Propulsion Directorate's Turbine Engine Division (AFRL/PRT) managed this activity which was jointly sponsored by the Air Force, Army, Navy, NASA, and the American Society of Mechanical Engineers (ASME). The only comprehensive history of the US aircraft gas turbine engine development ever written, the book traces the powerplant revolution that allowed the "Jet Age" to occur. Special emphasis is placed on revolutionary turbine engine technologies that resulted in dominance in the air for US military and



Cover of the recently published gas turbine book

commercial aircraft. As a result of this dominance, aerospace has the largest positive trade balance of payments of any sector of the US economy. (M. Stibich, AFRL/PRTF, (937) 255-8210)

TEAMING WITH NATIONAL LAB TO IMPROVE SUPERCONDUCTOR BUFFERS: The Propulsion Directorate's Superconductivity Group (AFRL/PRPS) is partnered with the Los Alamos National Laboratory to study the effects of substrate surface roughness on the ion beam assisted deposition (IBAD) process for YBCO (yttrium barium copper oxide) coated conductors. The IBAD process uses specially aligned beams of ions (assisting ion beam) to remove the yttria stabilized zirconia (YSZ) deposited in non-preferred orientations as the material is deposited on the metal substrate. As the YSZ buffer layer grows, it retains the crystal orientation that is not etched away by the ions. CeO_2 is then epitaxially grown on this layer by other processes followed by YBCO. Surface roughness is accepted in the coated conductor community as being important; however, it is acknowledged that a systematic study of its effect has not yet been performed. The current study is related to another performed by the AFRL Superconductivity Group (PRPS and MLPO) involving substrate surface roughness effects on the textured substrate approach. In that case, the metal substrate is textured by deformation and heat treatment processes after which a buffer layer is epitaxially grown on the substrate. The YBCO coated conductor is used in coil windings for cryogenic power generators required for airborne directed energy applications. (P. Barnes, AFRL/PRPS, (937) 255-2923)



Schematic of the IBAD process

ROQUEMORE NAMED AIAA FELLOW: Dr. W. Melvyn Roquemore of the Propulsion Directorate has been named a full fellow of the American Institute of Aeronautics and Astronautics (AIAA). A senior scientist in the Combustion Branch (AFRL/PRSC), Dr. Roquemore directs experimental and computational research in fundamental combustion and jet fuel thermal stability processes. He directs the development of laser diagnostics and advanced combustor concepts, such as the revolutionary trapped vortex combustor for advanced turbine engines. An AFRL Fellow, Dr. Roquemore leads two AFOSR Star Teams and has received the Propulsion Directorate's prestigious Heron Award on three separate occasions. He has established an international reputation through more than 150 technical publications. Dr. Roquemore is one of 30 AIAA fellows elected for 2000 and will be formally honored at AIAA's Global Air & Space 2000 International Business Forum and Exhibition in May 2000. (C. Eigel, AFRL/PRSC, (937) 255-6814)

Dr. Mel Roquemore

PROPELLANT FORMULATED FOR GREEN MISSILE: The Propulsion Directorate's Propellants Branch (AFRL/PRSP) is making significant headway in the SERDP (Strategic Environmental Research & Development Program) funded Green Missile Program. The Green Missile Program is a joint effort between the Air Force, Army, Navy, NASA, Environmental Protection Agency (EPA), and the Department of Energy (DoE). In this program, researchers are investigating pollution prevention alternatives in three areas: elimination of lead in minimum signature missile systems; elimination of HCl as a combustion product in smoky systems; and elimination of chlorinated/toxic solvents used in processing propellant oxidizers. The PRSP team aims to produce an environmentally enhanced, solid booster propellant incorporating ultrafine metal fuel. Toward this end, the first 2-liter batch of a solid propellant formulation incorporating a combination of ultrafine aluminum (UFAL) and magnesium/aluminum alloy was recently manufactured. Uniaxial tensile property characterization on prepared tensile specimens was performed and the propellant exhibited mechanical properties that are more than sufficient to allow small motor tests. A series of small motors were cast, and the effect of the new fuel on booster propellant ballistics will be one of the principal focuses. (A. Brand, AFRL/PRSP, (661) 275-5787)

HIGH RESPONSE VALVE SUCCESSFULLY DEVELOPED: Scientific Monitoring Inc (SMI), under the Propulsion Directorate sponsored "Smart Materials for High Response Flow Control" Phase I SBIR Program, has fabricated and successfully tested a high response valve. The goal of this program is to develop a high response fuel modulation valve for a broad range of turbine engine active combustion control applications. In the Phase I program, SMI successfully developed a high frequency actuator specification, valve design approach, and prototype hardware. Future challenges in the development include increasing the operating temperature to 900°F and the operating frequency to 500

Hz. Due to technological advances on the horizon, there is optimism about achieving these goals in a potential Phase II program. In a Phase II program, a development rig test version of the valve would be built and tested on a Pratt & Whitney active combustion control test rig. The high response fuel valve and actuator are critical components for future active combustion control (ACC) systems, and they form a critical link to a future intelligent turbine engine concept. These future engines will have significantly reduced high cycle fatigue (HCF), 30 percent reduced maintenance cost, reduced emissions, and for military engines with augmentors, 20 percent thrust improvement. (K. Semega, AFRL/PRTA, (937) 255-6690)

High response valve developed by SMI

HEX STUDY ON TRACK: The "HEX" Summer Study Working Group, which was formed to provide a multiple integrated technology thrust for developing Active Denial weapons technology, met on 28-29 October 1999 to further revise the design requirements of this technology. The main directorates involved in this advanced technology study include DE (Directed Energy), HE (Human Effectiveness), VA (Air Vehicles), and PR (Propulsion). A key propulsion initiative included in the study is power generation, which includes the prime power engine. The power subsystem work includes engine integration, generator development, cryogenic cooling system, and power conditioning options. High-temperature superconducting (HTS) power generation is an enabling technology for mobile directed energy applications whether for ground, airborne, or space operations. It is essential for both lethal and non-lethal applications as well as Active Denial technology. The power generation technologies being designed in the study will find use in both military and civilian applications. The technologies can be applied commercially for such applications as high efficiency superconducting motors and generators and power transmission cables with the coated conductor improvement. This study supports the Defense Technology Objective for Non-Lethal Technologies. (P. Barnes, AFRL/PRPS, (937) 255-2923)

FUELS BRANCH ASSISTS NASA WITH SHUTTLE STUDY: In October 1999, personnel from the Propulsion Directorate's Fuels Branch (AFRL/PRSF) provided expert assistance to NASA Glenn Research Center (GRC). NASA GRC is conducting a study of a non-toxic alternative propellant for the Space Shuttle Orbital Maneuvering System (OMS). The behavior of the alternative propellant, ethanol, was examined under OMS conditions in the NASA GRC Heated Tube Facility. In this experiment, propellants flowing at high velocities are exposed to high heat fluxes simulating regenerative cooling conditions in rocket thrust chambers and nozzles. PRSF assessed the post-test carbon deposition levels for NASA GRC using instrumentation that is employed routinely in PRSF to assess deposition from various JP and specialty fuels in a variety of test rigs. PRSF and NASA GRC have worked together a number of times assessing the behavior of fuels in the Heated Tube Facility. Most recently, a number of

tests were run in an initial assessment of JP-8 behavior under regenerative cooling conditions in copper channels. (T. Edwards, AFRL/PRSF, (937) 255-3524)

INVESTIGATING FRETTING FATIGUE: Ongoing research between the Propulsion Directorate's Components Branch (AFRL/PRTC), the Air Force Institute of Technology, and the University of Dayton is shedding new light on the mechanisms responsible for fretting fatigue crack initiation of the titanium alloy Ti-6Al-4V. Fretting is the damage that occurs due to the unintended relative motion of surfaces under large normal stresses. In this investigation, various loads were applied to obtain fretting fatigue crack initiation in both the low and high cycle fatigue regimes, and the experiments were modeled and analyzed with finite element analysis. The comparison of the experimental and analytical results showed that fretting fatigue crack initiation is dependent on the plane of maximum shear stress amplitude and the slip range at this location. Industry currently reduces the predicted life by half in regions where fretting fatigue is likely to occur; however, the current research suggests that this reduction is only necessary under conditions where the slip range is large. Below a specified slip range, fretting fatigue crack initiation is statistically similar to plain fatigue behavior; therefore, the life reduction is not necessary under all conditions of fretting fatigue. This research could lead to doubling the life of certain turbine engine disks. (C. Lykins, AFRL/PRTC, (937) 656-5530)

ANOTHER SUCCESSFUL MONOPROPELLANT TEST: Atlantic Research Corporation (ARC) recently performed a successful monopropellant thruster test at their Liquid Propulsion Facility in Niagara Falls, New York. This test was performed on a developmental monopropellant produced at the Propulsion Directorate's Propellants Branch (AFRL/PRSP). This particular propellant possesses a 61 percent improvement in theoretical density impulse over the industry standard propellant, hydrazine. During the test, the effects of propellant feed pressure and catalyst bed temperature were examined. A total of 27 test sequences were run including steady state and pulse tests. The AFRL Monopropellant Project is directed to develop high performance propellants capable of meeting the performance objectives of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program. These objectives include an increase in the propellant density impulse of 60 percent over that of hydrazine. This performance increase can enhance satellite missions in terms of increased satellite maneuvering lifetime, larger achievable maximum payload, or greater flexibility in satellite/thruster size. ARC expressed interest in continuing tests of this monopropellant and will forward a data package outlining its findings to AFRL. (T. Hawkins, AFRL/PRSP, (661) 275-5449)